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MINING, CRUSHING, AND GRINDING METHODS AND COSTS AT THE RELIANCE CEMENT ROCK QUARRY OF THE GIANT PORTLAND CEMENT CO., EGYPT, PA.

BY

S. G. McANALLY

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MINING, CRUSHING, AND GRINDING METHODS AND COSTS AT THE RELIANCE CEMENT-ROCK QUARRY OF THE GIANT PORTLAND CEMENT CO., EGYPT, PA.[1]

By S. G. McAnally[2]

INTRODUCTION

This is one of a series of papers describing mining and crushing methods and costs at cement plant quarries throughout the United States and deals directly with the methods employed and costs obtained at the Reliance quarry of the Giant Portland Cement Co. at Egypt, Pa., although it is more or less descriptive of the methods used throughout the Lehigh Valley cement district. Systems of transportation vary according to local conditions, such as proximity to the mill, depth of quarry floor with relation to the mill level, etc. Methods of prospecting differ mainly in the type of drills used. Systems of storage, crushing, and grinding vary chiefly in the types of units.

ACKNOWLEDGMENTS

Most of the information regarding the early history of the Lehigh cement district was obtained from the History of the Portland Cement Industry of the United States, by Robert W. Lesley, the first president of the Portland Cement Association. The writer is indebted also to Charles Clader, Giant Portland Cement Co. quarry superintendent, for valuable information regarding present and past methods and equipment.

Some information on the geology of the district has been gleaned from Prof. Benjamin L. Miller's report on the limestones of Pennsylvania. Other statements regarding the geology are based on personal observation and on the interpretation of the analyses of samples of rock from numerous test holes drilled over a large area.

HISTORY

The Lehigh Valley cement district was discovered and brought into being through the need of cement mortar in the construction of artificial waterways before the advent of the railroads.

About 1830 a small cement plant was built on the Lehigh Canal at Seigfried's Bridge, under the ownership of Gen. J. K. Seigfried, one of the pioneers of the industry. The natural cement manufactured was used largely in the construction of the Lehigh Coal and Navigation Co.'s canal from the coal regions to Easton, Pa. Other cement plants followed and the success of the natural-cement works in the Lehigh district led to the establishment, in the eighties, of a plant at Egypt, Pa.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6448."

[2] One of the consulting engineers, U. S. Bureau of Mines and chief chemist, Giant Portland Cement Co.

The Giant Portland Cement Co., originally the American Cement Co., was organized in 1883. In 1898 the company was operating four plants in the vicinity of Egypt. The kilns used were the upright, intermittent type, but in the latter year rotary kilns 60 feet long were installed at one of the above plants. In 1900 the Central mill was built and was equipped with rotary kilns only. The Reliance mill was built in 1905 and the present quarry was opened in the same year.

GEOLOGY

The cement rock of the Lehigh district, as found in the Reliance quarry, belongs to the Jacksonburg formation and is a continuation of a belt that extends from Belvedere, N. J., on the Delaware River, through Stockerton, Bath, and Northampton, to about 10 miles west of the Lehigh River. The belt is only a few miles wide, yet there are about 25 cement plants located on it.

The strata consist of a basal layer of crystalline limestone mixed with dolomite, and an upper layer of argillaceous limestone (cement rock) which comprises most of the formation. The northern boundary of the cement rock can sometimes be determined by an abrupt change in the topography, the line of contact being at the base of the steep slopes which mark the southern margin of the slate belt (Martinsburg formation) which overlies the Jacksonburg limestone. The southern boundary is sometimes marked by a change in slope to the more soluble underlying high-grade limestone (Beekmantown formation), but the geology is not regular.

In some areas large lenses of high-grade cement rock are embedded in very low-grade material; sometimes the rock is covered by residual clay to a depth of 50 feet. There are several large outcrops of dolomite which are probably overlain with cement rock.

The cement rock is a black slaty stone, intermediate in composition between limestone and slate. The calcium carbonate varies from 55 to 85 per cent. In the developed areas the variation is not so extreme and the rock will average about 75 per cent calcium carbonate. This is the approximate percentage required in the raw mix for the manufacture of Portland cement; hence the name "cement rock." The rock is comparatively soft and is laminated due to its slaty nature. Following is the analysis of the average cement rock from the Reliance quarry:

	Per cent
Silica	14.80
Iron oxide and alumina ..	7.20
Calcium carbonate	72.50
Magnesium carbonate	4.10
Water, alkalies, etc. ...	1.40

The above material must be mixed with some high-grade limestone in order to increase the calcium carbonate content to the desired percentage (about 75 per cent). Some cement companies in the Lehigh Valley are more favored than others in having, adjacent to their plants, deposits of limestone which can be quarried and delivered to the mill for the same cost as the cement rock. At some mills the cement rock is sufficiently high in calcium carbonate to require the addition of clay or other argillaceous material in order to regulate the mix. No workable deposit of high-grade calcium limestone has been discovered in the

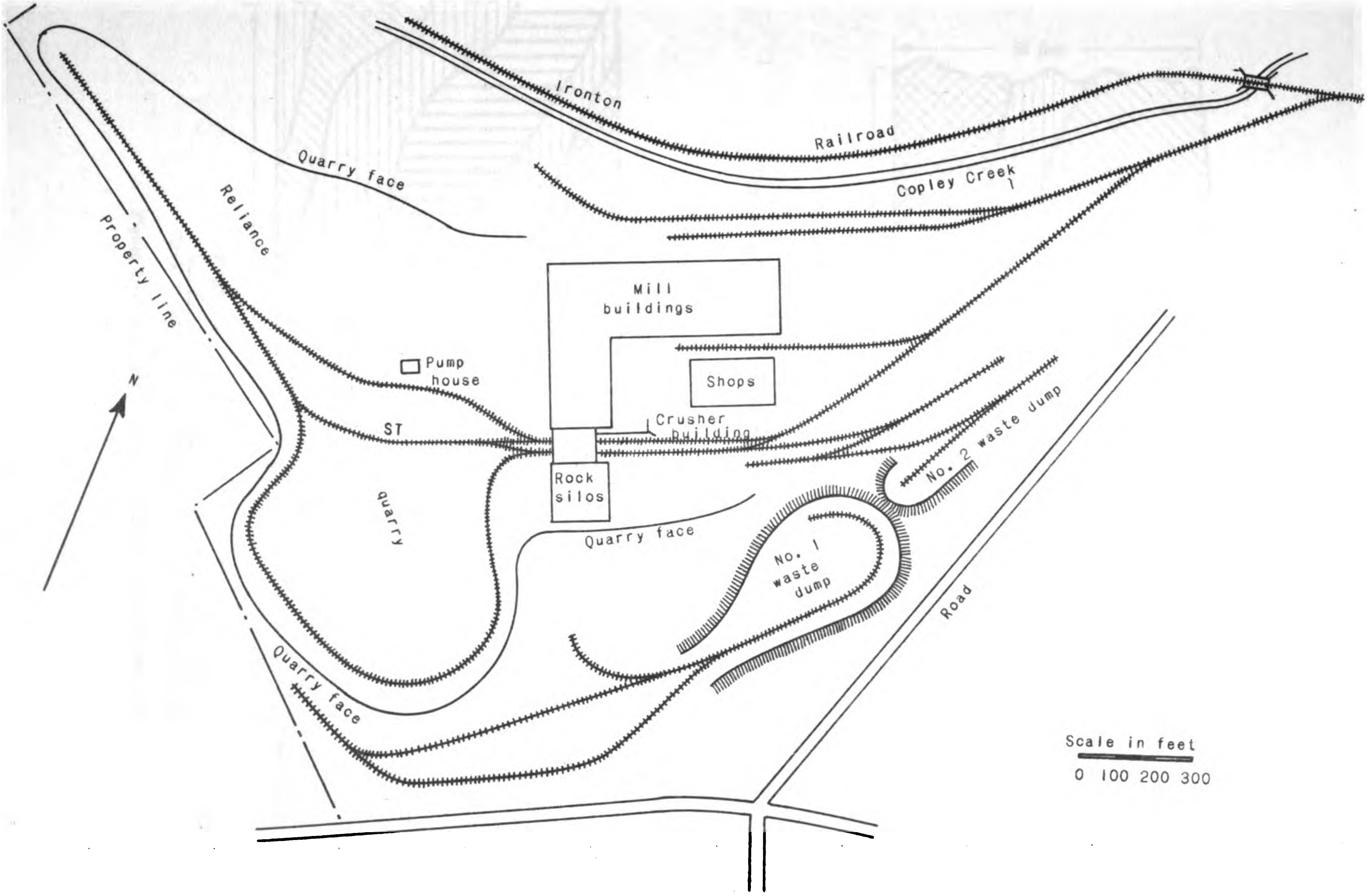


Figure I.- Plan of Reliance quarry

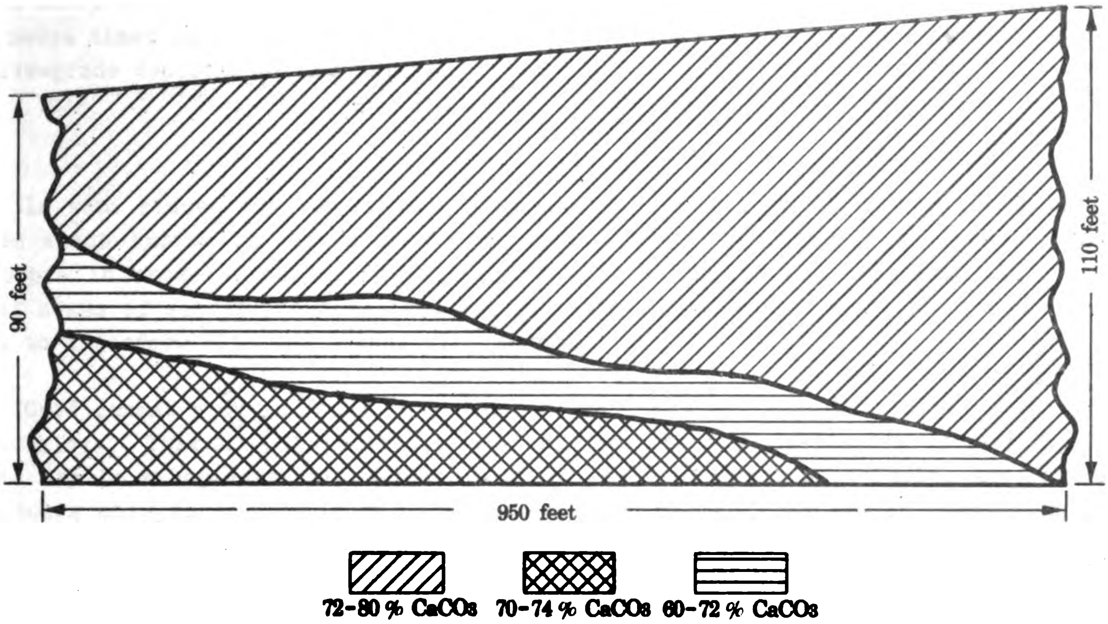


Figure 2.—Section of south face of quarry showing composition of strata

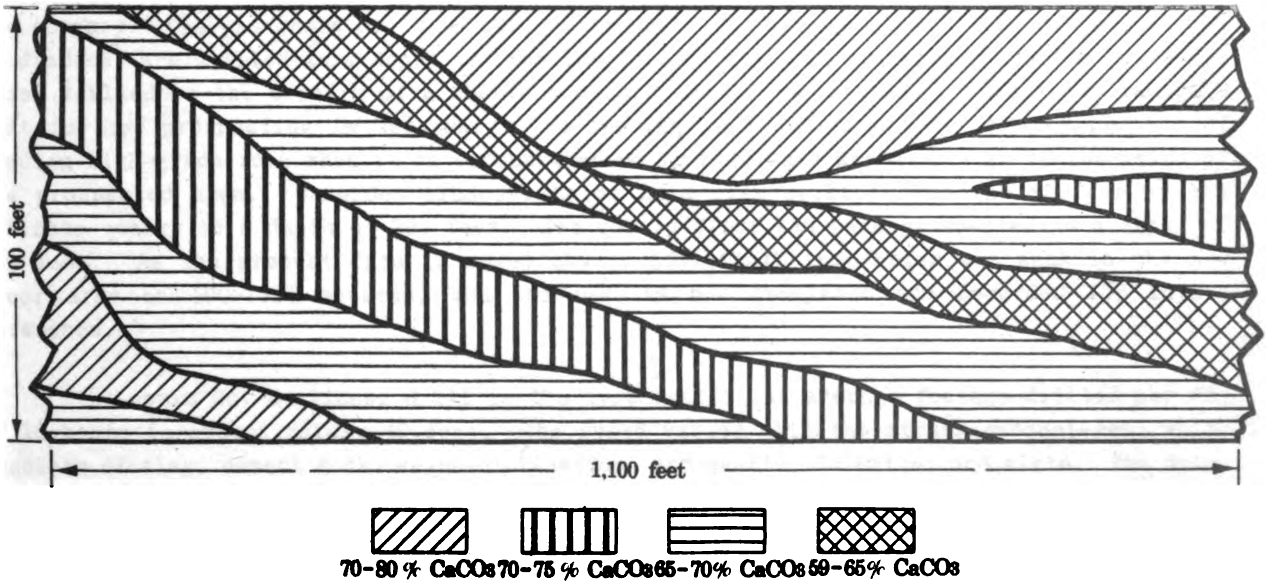


Figure 3.—Longitudinal section of rock below the quarry floor

vicinity of Egypt, and the limestone used at the Giant Portland Cement Co.'s plants is purchased and shipped from Annville, Pa. The cost delivered at the mill is $2.40 per long ton, or about seven times as much as the cost of the cement rock. Therefore it is not economical to work low-grade deposits of the latter.

RELIANCE QUARRY

In some places the cement rock outcrops, but as a rule it is covered by a clay overburden which varies in thickness from 1 to 20 feet. Sometines the clay extends to greater depth in pockets, chasms, fissures, or wide cracks in the otherwise solid rock. Occasional seams of quartz and soapstone are encountered but not in sufficient quantity or thickness to interfere with the method of quarrying.

Good cement rock is found to a depth of at least 230 feet within the area of the present workings. This area is located in the southeast section of the quarry (see fig. 1). The strata dip in a northwesterly direction at an angle of about 5°. Faults are rare and folding occurs only in a few places. The composition of the rock varies considerably in localized sections but the method of quarrying reduces this variation so that the rock delivered to the mill will average between 70 and 75 per cent calcium carbonate. A plan of the quarry and the track layout is shown in Figure 1. A section of the present face showing location of strata is shown in Figure 2. A longitudinal section of the rock below the floor of the quarry is shown in Figure 3.

PROSPECTING

Considerable prospecting has been done on the Reliance and adjacent properties of the company. One gas churn drill is used continually for this purpose. Test holes 6 inches in diameter are drilled to a depth of from 100 to 200 feet. In new properties the holes are first drilled on the corners of a 250-foot square and if the results of the tests indicate that further prospecting is necessary, the spacing is reduced, either for the purpose of tracing high-grade rock when it is encountered or to eliminate any doubts as to the value of the prospected area. Numerous prospect holes have been drilled from the surface of the Reliance quarry to a depth of 230 feet. The quarry floor has been prospected to a depth of 100 feet. As the present face is moved ahead, additional test holes are sunk in the new floor area on 100-foot squares, and the results are tabulated and recorded for future reference.

Loomis No. 4 clipper drill is the type used. The average footage drilled per day of 10 hours is approximately 40 feet. The speed varies with the strata encountered, which consists of clay, cement rock, veins of limestone and quartz, dolomite, and slate. The dolomite is the hardest rock encountered in large masses. The rate of drilling becomes slower with increasing depth. When water is encountered in the drill holes the footage drilled in unit time is much less than the average. The average cost of drilling prospect holes is $0.405 per foot. This cost includes labor (two men to a drill), material and fuel, repair labor, and also covers the time used in moving from one location to another.

METHODS OF SAMPLING AND ANALYSIS

Samples are taken from each 5 feet of drill hole. Each time the sludge is bailed out the first portion is thrown away and the second fill of the bailer is caught in a water pail; all other bailings are thrown away. The sample in the pail is washed free from clay, is mixed well, and put into a small tin box or a tobacco can, several of which are provided for the purpose. Each can is marked with the number of the test hole and the depth at which the sample was taken.

Samples are dried and pulverized and a determination for carbonate, in terms of calcium carbonate, is made on each one by the simple and rapid acid-alkali method. After all samples from one hole are tested in the above manner a composite is made of all the samples of that hole. A carbonate determination is made on the composite; the result should agree with the arithmetical average of the individual results within 0.2 per cent. The actual lime in the composite, determined by the potassium permanganate method, is calculated to calcium carbonate. The difference (plus or minus value) between the actual calcium carbonate and the carbonate obtained by the acid-alkali method is added to the individual results so as to obtain the correct values. The composite samples are also analyzed for magnesia.

In using the acid-alkali method for the estimation of calcium carbonate in limestone, cement rock, and cement mixes, it is customary to standardize the acid and the alkali solutions with a standard sample of material approximating the composition of the samples to be tested. If the standard sample contains 42 per cent lime (75 per cent $CaCO_3$) and 2 per cent magnesia, a sample of rock which by this method analyzes say, 70 per cent calcium carbonate, contains the equivalent of 70 per cent $CaCO_3$ and 2 per cent MgO. But if the actual MgO is more than 2 per cent, then the $CaCO_3$ will be less than 70 per cent, and as the percentage of magnesia may vary in different sections and strata of a property, it is necessary to make a determination of the lime in the composite in order to check and make any correction of the acid-alkali determination.

When the acid-alkali result exceeds the actual calcium carbonate content, the difference, especially if considerable, can be attributed to a higher percentage of magnesia than that in the standard sample. This difference multiplied by 0.4 will equal approximately the increase in the percentage of magnesia. Other acid-soluble basic impurities affect the acid-alkali determination, but to a less degree.

ESTIMATION OF TONNAGE

Based on the analyses, areas are mapped out so that the average calcium-carbonate content of the whole area will exceed 70 per cent. The available tonnage is estimated on the basis of 155 pounds per cubic foot. Due to the fairly regular and solid formation of the rock, especially below the quarry floor, the tonnage can be estimated closely.

METHODS OF QUARRYING

The open-pit method of quarrying has been used from the beginning of operations in the Reliance quarry. The first cut was made at the mill site in order to excavate for the crusher and adjacent buildings. The area extending from the mill to the northwest was the first developed and worked due, no doubt, to the fact that it had less than 1 foot of overburden. When the good rock in this section became exhausted, or nearly so, the area to the southwest was prospected and developed. The overburden in this area consists of a yellow clay. The amount of clay per thousand tons of cement rock is approximately 100 cubic yards. This estimate applies only to the southwest area.

This heavy clay overburden is removed by stripping with a power shovel and a dragline scraper supplemented with some pick and shovel work. Due to the clay-filled crevices previously mentioned which, in part, can not be stripped by the regular methods with economy and safety, some waste is shot down with the rock. The waste removed in the quarry proper by the power shovels and transported to the No. 2 waste dump amounts to approximately 2 per cent of the rock recovered. A certain amount of waste is unavoidably mixed with the rock going to the mill but it is only harmful in that it requires a larger amount of the expensive limestone to regulate the mix.

Considering the nature of the overburden and its amount, the fact that 98 per cent of the material shot down can be recovered, that high and long working faces are possible, the open-pit method and the use of power shovels is logical and economical.

DRAINAGE

The present quarry floor is on the same level as the mill site but it is low with respect to the surrounding country. The maximum height of the quarry face above this level is 120 feet. However, due to the proximity and greater depth of other quarries, no drainage is necessary at present in the Reliance quarry. When the supply of cement rock above the present floor level is exhausted and if it is decided to sink deeper so as to recover the good rock below, it will then be necessary to provide for drainage.

STRIPPING

Stripping operations are carried on between April and October. The first cut is made with a Bucyrus steam shovel with a ¾-yard dipper. This is followed later by a Marion steam shovel which has been converted into a dragline scraper and equipped with a ¾-yard Page scraper bucket. Most of the clay is found in wide chasms and long crevices and the dragline is very suitable for removing it. In the narrow lateral crevices which are inaccessible to the scraper bucket several men are employed to dig the clay and shovel it into the path of the bucket. All overburden is removed as far as possible.

The clay is loaded directly into Easton side-dump cars. The cars hold 1¼ cubic yards and are hauled to the No. 1 waste dump by Vulcan steam locomotives. A train consists of six cars. The dump is located on the slope of a hill. The length of haul from the stripping area to the dump is between 1,500 and 2,000 feet; the grade is less than 2 per cent The track layout is shown in Figure 1. The gage is 30 inches and a 24-pound rail is used.

The average amount of overburden removed in 10 hours is 175 cubic yards; this figure applies to the dragline operation in which the stripping is tedious and expensive due to the awkward position of the clay. The dragline scraper and two locomotives are used at present. The stripping crew consists of 14 men as follows: 2 men on the dragline, 1 man on each locomotive, 6 pick-and-shovel men to supplement the scraper, and 4 men on the waste dump to empty cars and level off. One foreman has charge of stripping, drilling, and prospecting.

The total cost of stripping over a period of four years amounts to $0.599 per cubic yard.

Stripping operations are kept well ahead of drilling, and enough rock to supply the mill for about two years has been stripped.

MINING

In mining, the general plan is to develop long and high faces so as to bring down with one shot sufficient rock to supply the mill for several months. The Reliance mill requirements are between 25,000 and 30,000 long tons per month. The Central mill, when operating, requires about 18,000 tons per month. Both mills are supplied from the Reliance quarry. All the rock is used in the manufacture of cement. Waste inclusions amount to about 3 per cent of the rock. About two-thirds of this can be easily segregated, loaded separately, and transported to the No. 2 waste dump which is located close to the stripping dump but at a lower level on the side of the same hill. The haul to the lower waste dump is too steep to be made directly; it is accomplished by making one long level haul and three short hauls of 4 per cent grade. The total length of haul from the quarry face to the lower waste dump is approximately 3,500 feet.

The quarry face is perpendicular. From the east to the west side the height of the face increases from 85 to 110 feet. A circular face is developed. It is believed that this form of face gives the best blasting results with respect to the amount of explosives used per ton of rock for primary and secondary blasting.

PRIMARY DRILLING

Churn drills made by the Loomis Machine Co. are used for the primary drilling (and for prospecting). There are two gasoline drills, model JA, one traction and one half-caterpillar, and two steam drills, one traction and one horse-drawn. The gasoline drills are preferred as they are found to be more economical to operate and are more convenient with respect to supplies, such as fuel and water. A horse and cart delivers the coal from the mill to the steam drills, dragline, and to the locomotives. The driller's helper brings the gasoline in 5-gallon cans from the mill. A pipe line from the mill to the top of the quarry delivers either water or air. The air pressure is 65 pounds. The air is used for operating an I. R. jackhammer when it is found necessary to blast some of the rock in order to level the surface or to fill in some of the crevices prior to locating the churn drill. Where the crevices are wide, the churn drill rests on a cribbing made from railroad ties.

Oil-well drill steel 5⅝ inches in diameter is used. Drill bits weigh 250 pounds and are dressed to 6½ inches diameter. Drill stems measure 4¼ inches by 20 feet. The bits are dressed in an Armstrong bit dresser. Casing is used only in clay or loose material.

The average drilling speed is 45 feet per day of 10 hours. When in hard rock, bits have to be changed and dressed oftener so as to maintain a uniform diameter of the hole.

Holes are spaced 15 feet apart, parallel to the face, and cary a 28-foot burden. Where it is impractical, due to extreme irregularities of the top surface, to drill parallel to the face the holes approach or recede from it, depending on the apparent degree of solidity of the rock at that point. Formerly it was the practice to increase the spacing in the more solid rock but this procedure was discontinued as it was found to make the cost of secondary blasting too high. The number of holes drilled for one shot ranges from 35 to 45. The diameter of the holes is 6¼ inches; the depth is governed by the height of the face which varies from 85 to 110 feet. All holes are drilled 6 feet below the quarry floor.

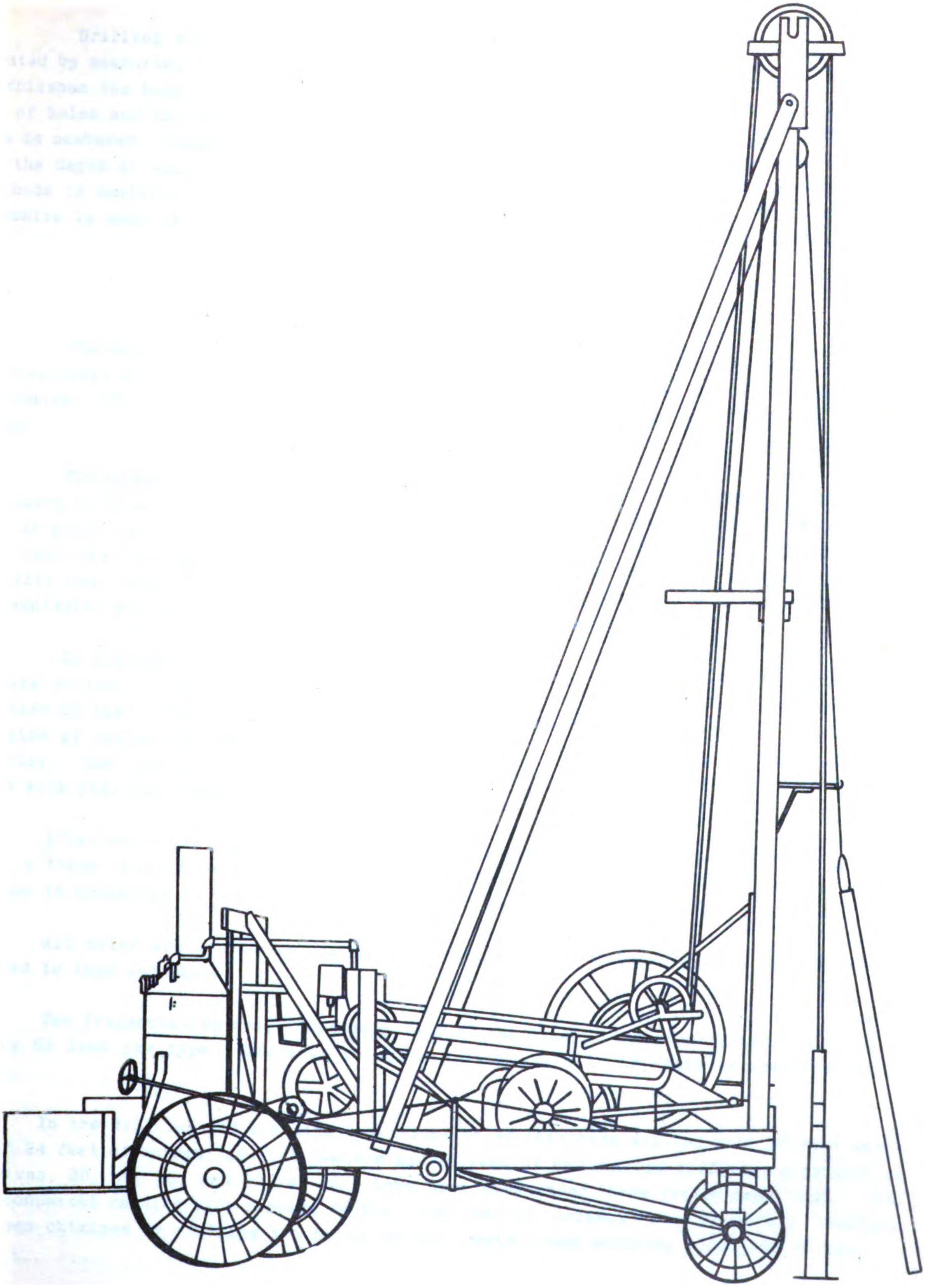


Figure 4.- Steam well drill

Drilling starts immediately after each shot is made. Positions of the holes are located by measuring from permanent stakes the exact distances toward the quarry face; this establishes the base line for the row of holes. A record is kept of the location of each set of holes and the position of each hole is plotted on a blue print of the quarry. Each hole is numbered. Samples are taken every 5 feet and are marked according to the hole number and the depth at which the samples were taken. The samples are treated as described under "Methods of Analysis." They are stored until after the shot is made and the stone used. A composite is made of samples of all holes in the blast, and a complete analysis is made of it.

PRIMARY BLASTING

The explosives used for primary blasting are 60 and 40 per cent gelatine dynamites. The cartridges are 5 inches in diameter and 24 inches long. Cordeau is used for detonating the charge. No. 6 detonators and Beaver fuse (speed 40 seconds per foot) are used for firing.

The powder used for primary blasting is not kept in storage but is delivered to the quarry by auto trucks on the day the shot is to be fired. It is distributed to all the holes in proportion to the amounts and the strengths required. The boxes are opened by extra labor (not the loading crew). There are from two to four loading crews of three men each. They fill the holes in rotation and under the the supervision of the explosive company's representative who acts as powderman and who is responsible for the shot.

In loading each hole the cordeau is attached to the bottom stick of powder. As a rule the bottom is loaded with the 60 per cent powder and the top with 40 per cent. The thickness of the burden at different heights also governs the distribution of the different strengths of explosive. When pockets are encountered, that portion of the hole is filled with clay. The holes are loaded to within 20 to 25 feet from the top and the remainder is filled with clay and tamped down.

After all holes are loaded the ground is cleared of powder boxes and other obstructions, a trunk line of cordeau is run from the first to the last hole, and the free end of the line is connected to the detonator and fuse. The fuse is lighted with a match.

All holes are loaded and fired on the same day. Between 10 and 15 minutes are required to load each hole.

The fragmentation desired is dependent on the size of the primary crusher which is a 48 by 60 inch jaw type. There is no minimum limit as all the stone is used for making cement.

In the drilling and blasting operations holes have been drilled with 16-foot centers and 24 feet of burden; 18-foot centers and 26 feet of burden; and different strengths of explosives, 30, 40, 50, and 60 per cent have been used under these varied conditions. The most economical results with respect to the total cost of primary and secondary blasting have been obtained by drilling the holes 15-foot centers and carrying a 28-foot burden.

SECONDARY DRILLING AND BLASTING

Ingersol-Rand jackhammers, type BCR4, are used for drilling the large bowlders. The air is delivered from the compressor to the quarry over a 2-inch line. Several 1¼-inch air lines branch out from the main line to different sections, and ¾-inch leads connect the main line to the drills. The air pressure at the drills is between 70 and 80 pounds.

The drill steel is ⅞-inch hexagon stock; 1¼-inch bits are used for 1½-inch diameter holes, and 1¾-inch bits for 2-inch holes. In large bowlders in which the depth of the holes exceeds 10 feet, the holes are made 2 inches in diameter; shallower holes are made 1½ inches in diameter. The drilling speed is about 1 foot in 4 minutes.

The large bowlders encountered by the steam shovels are cast to one side and drilled by a crew of two men used for this purpose and for barring down loose bowlders which are also drilled. Holes are drilled to the centers of the bowlders. The dynamite used is 1¼ inch diameter 40 per cent gelatin. No. 6 detonators and Beaver fuse (speed 40 seconds per foot) are used for firing. The holes are filled to within 2 inches of the top with the powder, the cap and fuse are attached to the last stick, and the last 2 inches of the hole is filled with clay and tamped well. The fuses are cut to not less than 30 inches and are lighted with a wick.

In primary blasting the shots will average 3.7 tons per pound of explosive; in secondary blasting the ratio is approximately 1 pound of explosive to 44 tons of stone.

LOADING STONE

Two Bucyrus No. 70 traction-type steam shovels are used for loading the stone. The dippers are 2½-yards capacity. One Bucyrus No. 65 is held in reserve. Two shovels are able to load between 180 and 190 long tons per hour; this includes the intermittent stops caused by transportation delays. There are 3 men on each shovel; an engineer, a fireman, and a craneman. Working 8 hours per day and 5 days per week, the mill requirements of from 25,000 to 30,000 long tons per month can be supplied.

TRANSPORTATION

Three Vulcan steam locomotives running on standard gage 60-pound rail are used to transport the rock to the crusher. The grade to the crusher is practically level. Atlas 10-ton side-dump cars are used. The load in each car is 7½ long tons. Five cars make up a trainload. The fuel used on the locomotives, shovels, etc., is run-of-mine coal. It is hauled by a horse and cart to the shovels from a storage pile located on the track adjacent to the pump house. The locomotives obtain their coal from the same source. The water for the boilers is treated by the lime-soda process.

From the crusher to the quarry face the locomotives follow the horseshoe track around the face and make the return trip with the load over the straight piece of track (ST, fig. 1). The cars receive half of their load from the shovel nearer to the mill, and the load is completed by the further shovel. This loading system helps to mix the rock and reduces the variation in the composition. The haul to the crusher is about 1,200 feet.

The total quarry crew (exclusive of the men on primary drilling, blasting, and stripping) consists of 17 men; 3 on each shovel, 1 man on each locomotive, 2 powdermen for secondary drilling and blasting and for barring down, 2 pitmen, 2 track repairmen, 1 man at the crusher to dump cars, and 1 foreman.

CRUSHING PLANT

The primary crusher is located below the level of the tracks and rests on a solid rock foundation. Figure 5 is a sectional view of the silos and the crushing equipment.

A small drum hoist geared to a 15-hp. motor is used for unloading the cars. The lift is applied through an overhead block and tackle. The cars are dumped directly on to a 5 by 12 foot Traylor Sheridan grizzly feeder which is driven by a variable-speed 25-hp. motor. The feeder has a reciprocating motion and carries the rock ahead slowly and uniformly to a 48 by 60 inch Traylor jaw crusher belted to a 200-hp. motor. The fines, 3 inches and under, pass through the grizzly bars. The by-passing of the fines which contain most of the clayey material prevents choking of the crusher. The capacity of the primary crusher is 250 tons per hour crushing to 8 inches.

The crushed product and the fines which pass the grizzly are picked up by a 48-inch by 60-foot link-belt bucket elevator and delivered to the secondary crusher, a 42 by 48 inch Jeffrey swing-hammer mill directly connected to a 200-hp. motor. No intervening storage bin is required. The Jeffrey mill is very efficient for crushing cement rock. In order to reduce dust losses in the dryer stack several of the mill hammers have been removed.

The Jeffrey product, 3 inches and under in size, drops through a side chute to the lower run of a link-belt carrier which is driven by a 50-hp. motor. The buckets are 30 by 36 inches and overlap each other. The capacity of the carrier is 300 tons per hour. The carrier passes over a Merrick weightometer which weighs and records the quantity of rock going to the storage silos.

There are eight round concrete silos (two rows of four) with an intersticial row star shaped. The storage capacity is 12,000 tons. One section of the silos is 65 feet deep (inside depth) and the other is 40 feet deep. The latter is built over the railroad tracks, and double duplex gates 24 by 24 inches are attached to the bottom of these four silos. This permits the crushed rock to be loaded into gondolas and shipped to the Central mill of the company.

A traveling tripper is used for dumping the carrier buckets containing the crushed rock into any of the silos. A small back-geared drum hoist driven by a 2-hp. motor pulls the tripper in a counter direction to that of the carrier; the forward movement is effected by the pull of the buckets.

The empty buckets descend at the rear end of the silos and travel through a tunnel under the latter. Under each silo there is a link-belt, reciprocating feeder. The feeders are driven through chain drives and clutches from a line shaft which is driven by a variable-speed 10-hp. motor. They can be adjusted to withdraw the rock at a uniform rate from any number of silos at the same time. By feeding from several silos simultaneously, the rock is blended and the combined flow of material is more uniform in composition than that which entered the silos.

The feeders deliver the rock to the lower run of the carrier which conveys it to a point ahead of the secondary-crusher discharge chute. At this point a tripper dumps the blended rock into the boot or pit of a 36-inch by 96-foot link-belt bucket elevator (elevator No. 2, fig. 5) driven by a 40-hp. motor. The empty carrier buckets travel a few feet forward and pick up the product of the secondary crusher as already described. In case of a shut-down of the carrier the product of the secondary crusher or the crushed rock in the two north end silos can be fed directly to the No. 2 elevator which delivers the rock to the mixer bins.

In the crushing department there are five men and a foreman. The three silo men, one on each 8-hour shift, keep the mixer bins supplied with cement rock and limestone; the latter is stored in two of the silos. One man operates the upper tripper (which distributes the rock to the silos) and collects an average daily sample of the rock from the carrier buckets. The sixth man helps in the unloading of cars of limestone and does odd jobs.

DRYING AND MIXING

There are two reinforced concrete mixer bins each having a capacity of 200 tons. One is used for cement rock and the other for the crushed limestone. The mixing room is located under thses bins. Here the cement rock and the limestone are proportioned to make the raw cement mixture. The bins are equipped with duplex gates through which the stone feeds into the hopper of the Toledo scale. The hopper is drop-bottom and discharges at a uniform rate onto a horizontal belt conveyor, 39 inches by 7 feet 3 inches, which carries the mixture to a 16-inch by 35-foot overlapping bucket elevator. The latter delivers the product onto another horizontal belt conveyor 36 inches by 14 feet, to be discharged into the cylindrical dryer. The head pulley of the latter conveyor is a 16-inch diameter magnetic separator which picks the tramp iron from the stone.

The dryer, 8 by 80 feet, is direct fired by pulverized coal and can dry 67 tons per hour. Between 1,100 and 1,300 tons are dried each 24 hours. The dryer, the bucket elevator, the belt conveyors, and the auxiliary conveying equipment for cleaning the dryer stack chamber, are driven by a 75-hp. motor through a Cleveland Worm and Gear Co. speed reducer.

The dryer discharges directly into a 42 by 48 inch Jeffrey hammer mill direct-connected to a 75-hp. motor. Originally this mill was one of two installed for secondary crushing. One was found to be sufficient and the other was used to replace a smaller type of hammer mill at the discharge end of the dryer. The main purpose of this tertiary crushing is to break any stray large lumps of stone. The rock is reduced to under 1-inch size and discharges into an inclosed 17-inch by 40-foot bucket elevator which elevates it to a large rectangular steel bin located over the preliminary grinding mills. The bin has a capacity of about 100 tons.

There are three men in the mixing department, one man on each shift of 8 hours. There are no men in the drying department. The dryer, once started, requires little attention and that is given by the men in the grinding department.

GRINDING

The preliminary grinders are two Bradley Hercules mills. Each is direct-connected to a 300-hp. synchronous motor. The mills are equipped with 9-mesh screens and have an output of 40 long tons per hour per mill.

Screen Analysis of Hercules Product

Mesh	Per cent undersize
200	54.2
100	62.4
80	68.1
50	75.0
30	88.2
20	98.5
10	100.0

The ground material discharges into a 24-inch by 45-foot bucket elevator. The latter discharges into a 24-inch by 60-foot screw conveyor which distributes the material into a steel blending bin. The elevator and conveyor are chain driven from a Palmer-Bee Co. speed reducer coupled to a 25-hp. motor. There are five discharge openings in the conveyor casing. The first four are equipped with steel slides which are operated by an electrical device that opens and closes them in rotation. This insures a uniform distribution of the material entering the blending bin. The lower section of the bin consists of five hoppers, the centers of which are directly under the conveyor openings. Under the hoppers there are five rotary valves driven through chain drives from a line shaft. The valves withdraw the mix from the bin at a uniform rate and the five streams feed into an 18-inch by 50-foot screw conveyor. This discharges into a 17-inch by 25-foot bucket elevator which in turn discharges into an 18-inch by 66-foot screw conveyor which feeds the tube mills. The valves, the two 18-inch screw conveyors, and the last elevator are all driven by a 25-hp. motor through a Palmer-Bee Co. speed reducer.

There are two tube mills for the final grinding of the raw mix. One is a 7 by 26-foot Traylor and the other is a No. 20 7-foot by 23-foot 6-inch Smidth. The former is driven by a 500-hp. synchronous motor; the latter by a 400-hp. synchronous motor. The mills are charged with $\frac{3}{4}$-inch steel balls and cylpebs. The charge in the large mill is 35 tons; in the smaller mill 24 tons. The combined output of both mills is about 50 tons per hour. Ninety per cent of the product passes a 200-mesh screen.

The grinding department operates 24 hours per day, seven days per week. Six men, two on each 8-hour shift, are employed in this department.

REPAIR SHOP

There is a large and well-equipped repair shop at one end of which is the blacksmith's shop. A 12 by 10 inch, class 38, Pennsylvania Pump and Compressor Co. compressor supplies the air for the jackhammers and for miscellaneous purposes. An Armstrong bit dresser for the well-drill bits and a Denver Rock and Drill Co. bit dresser for the air-drill bits are part of the blacksmith shop equipment.

Repairs on the shovels and the locomotives are made without delay. The men operating these units work on a bonus system and the equipment for mining and transportation is kept in good condition at all times. All boilers are cleaned out every two weeks.

POWER

Electrical power is purchased from the Pennsylvania Power and Light Co. The substation equipment consists of two 3,000 kva. transformers and two 100-kw., 220-volt, direct-current motor generators. The incoming power is stepped down from 66,000 to 440 volts.

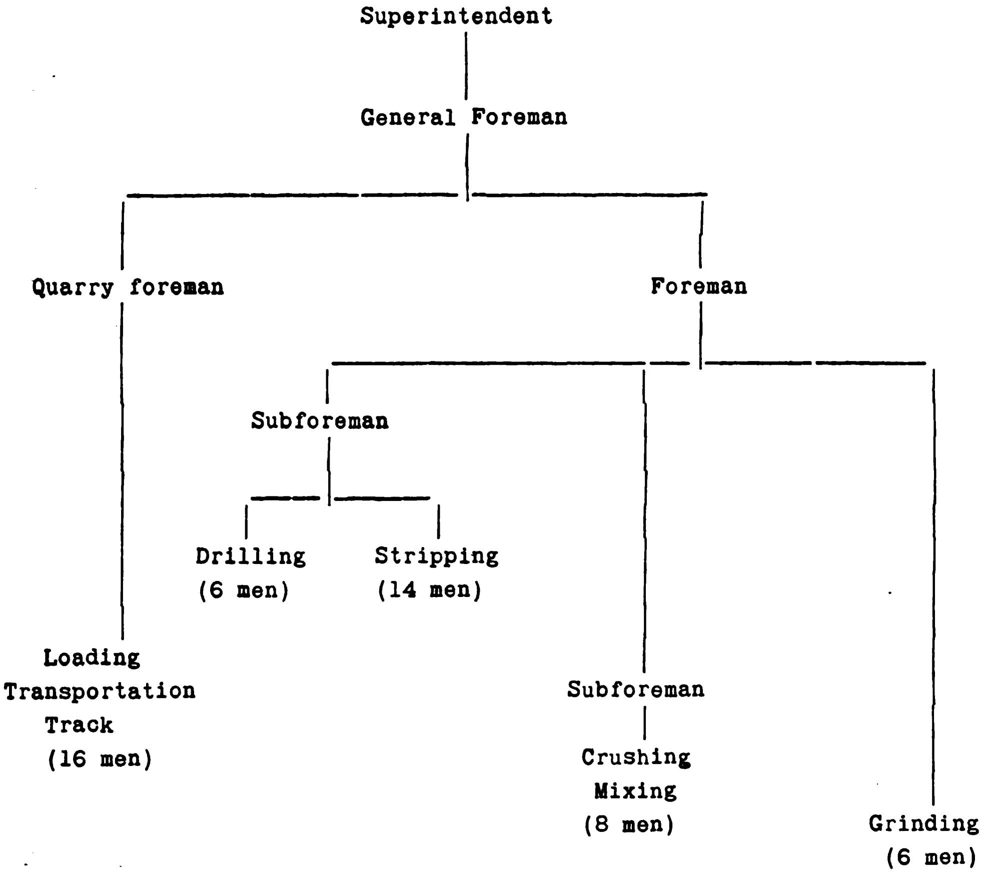
PAY SYSTEM

The men employed on stripping, primary drilling and blasting, and in the crushing and grinding departments are paid a straight hourly wage. The crew engaged in transportation, loading, and unloading of the cement rock is paid an hourly wage and a bonus. There are 16 men included in the bonus distribution. The bonus is based on a fixed labor cost and the actual labor cost for transportation, loading and unloading. A maximum labor cost of 8 cents per long ton is the present fixed standard. The difference between the maximum and the actual labor cost is paid to the men.

The wage scale is as follows:

Position	Number	Rate per hour
Shovel engineers	3	$0.53
Shovel firemen	3	.47
Shovel cranemen	3	.48
Well drillers	3	.495
Well drillers' helpers	3	.425
Drillers (jackhammer)	2	.505
Pitmen	2	.45
Locomotive engineers	5	.51
Trackmen	2	.465
Men on waste dump	4	.40
Pick and shovel men on stripping	6	.40
Blacksmith	1	.60
Tripper man (mill)	1	.45
Silo men	3	.46
Mixer men	3	.425
Millers	3	.58
Millers' helpers	3	.53
Subforemen	2	.58

ORGANIZATION CHART



COSTS

	Period covered, 1929.
Production of stone (short tons)	288,528
Overburden removed (cubic yards)	26,956

1. Summary

	Cost per ton
Stripping	$0.05599
Primary drilling and blasting	.06606
Secondary drilling and blasting	.00855
Loading	.07454
Transportation	.05258
Primary and secondary crushing and storage	.07720
Drying, mixing, tertiary crushing and grinding	.36378
Total	$0.69870

2. Stripping

Labor	$0.03627
Purchased power	.00004
Fuel	.00467
Other supplies	.01500
Total	$0.05598

3. Primary drilling and blasting

Labor	$0.01015
Explosives	.04571
Fuel	.00206
Other supplies	.00814
Total	$0.06606

4. Secondary drilling and blasting

Labor	$0.00600
Explosives	.00250
Other supplies	.00005
Total	$0.00855

5. Loading stone (shovels)

Labor:	
Operating	$0.02200
Repair	.00450
Pitmen	.00560
Cleaning quarry	.00088
Teaming	.00375
Foreman	.01082
Purchased power	.00030
Fuel	.00973
Other supplies	.01696
Total	$0.07454

6. Transportation

	Cost per ton
Labor:	
Operating locomotives	$0.02140
Repairing locomotives	.00481
Repairing tracks	.00239
Moving tracks	.00965
Repair material:	
Locomotives	.00346
Tracks	.00155
Moving tracks	.00032
Purchased power	.00030
Fuel	.00766
Oil and waste	.00104
Total	$0.05258

7. Primary and secondary crushing and storage

Labor:	
Operating	$0.04168
Repairs	.00293
Supplies:	
Operating	.00033
Repairs and maintenance	.01045
Oil and waste, tools	.00745
Fuel	.00063
Purchased power	.01373
Total	$0.07720

8. Drying, mixing, tertiary crushing and grinding

Labor:	
Operating	$0.05449
Repair	.03649
Supplies:	
Operating	.00062
Repairs and maintenance	.03158
Tools	.00007
Oil and waste	.00753
Fuel	.02947
Purchased power	.20353
Total	$0.36378

9. Summary of cost distribution

	Labor	Power	Fuel	Explosives	Other supplies	Total
Stripping	$0.03627	$0.00004	$0.00467		$0.01500	$0.05598
Primary drilling and blasting	.01015		.00206	$0.04571	.00814	.06606
Secondary drilling and blasting	.00600			.00250	.00005	.00855
Loading stone	.04755	.00030	.00973		.01696	.07454
Transportation	.03825	.00030	.00766		.00637	.05258
Primary crushing		.00574				
Secondary crushing		.00348				
Storage in		.00180				
Storage out	.04461	.00271	.00063		.01823	.07720
Mixing, drying		.01864				
Tertiary crushing		.00401				
Preliminary grinding		.04963				
Final grinding		.12824				
Conveying, etc.	.09098	.00301	.02947		.03980	.36378
Totals	$0.27381	$0.21790	$0.05422	$0.04821	$0.10455	$0.69869

10. Man-hours

	Man-hours per ton	Tons per man-hour
Stripping and drilling	0.13900	7.19
Loading and transportation	.12608	7.93
Crushing	.11696	8.55
Drying and grinding	.17914	5.58

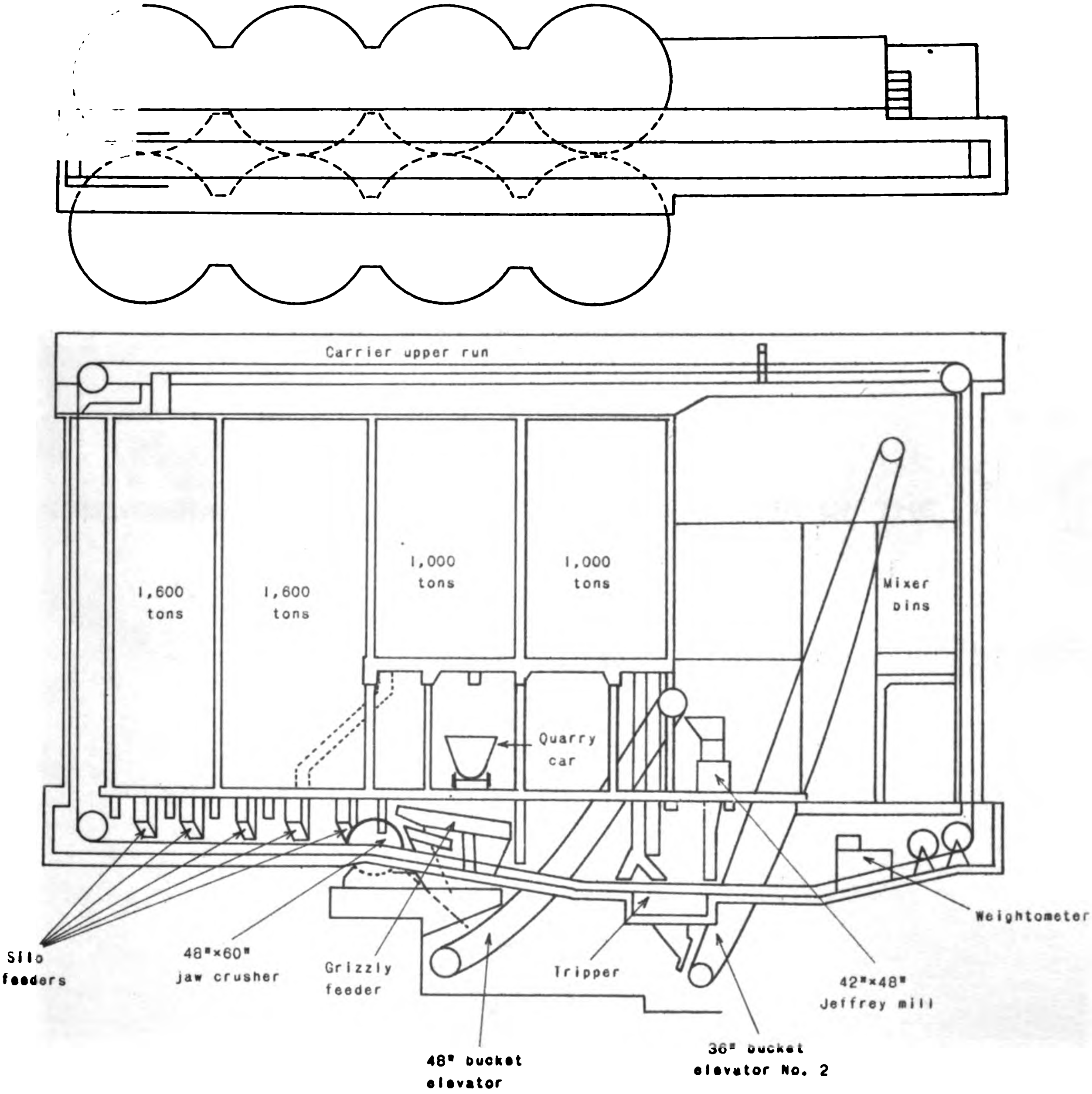


Figure 5.- Sectional view of silos and crushing plant